3D Rotational Angiography for Percutaneous Interventions in Congenital Heart Disease

38

Gregor Krings

38.1 Introduction

3D rotational angiography (3DRA) is an evolving technique that delivers computed tomographic imaging at the heart catheterization suite. A 180 ° rotation of the frontal plane during an interval of 4–7 s produces a rotational angiography (RA) when contrast is injected simultaneously with vendor-specific differences in the post processing.

38.2 Rotational Angiography

In a historic publication, Professor Schad/Stuttgart (Schad 1964–1966) demonstrated the value of rotational angiographies in congenital heart disease with the patient being fixed in a cradle and moved around the static C-arm. It took 40 years until complex algorithm (Kehl/Vogt, Frauenhofer 1999) allowed for computed conversion of the single rotational frames into stacks known from CTA or MRA.

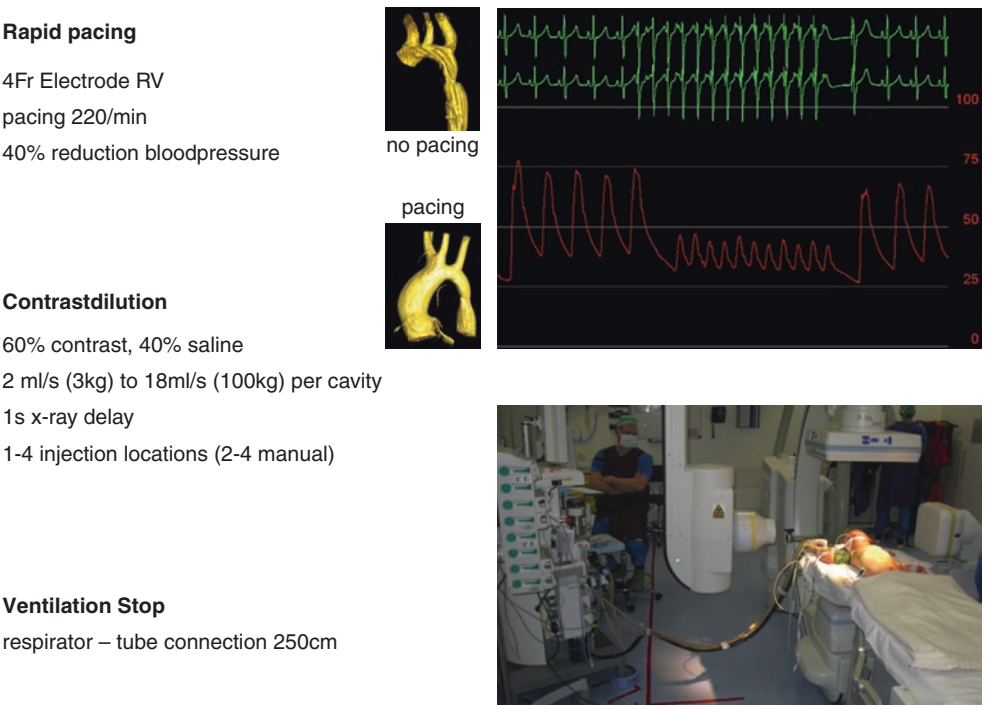


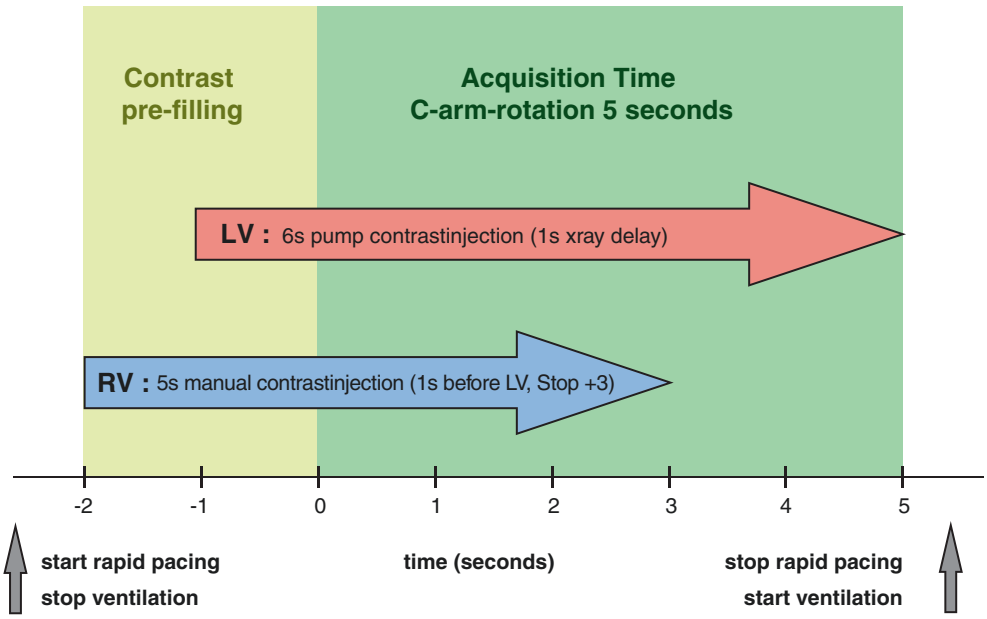
Fig. 38.1 3DRA workflow

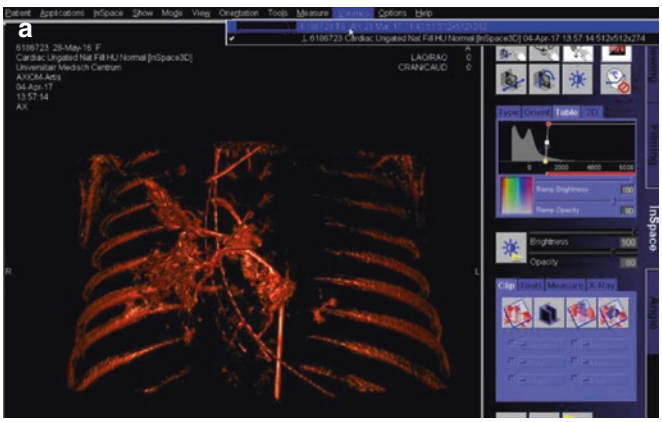
Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-319-72443-0_38) contains supplementary material, which is available to authorized users.

G. Krings (✉)
University Medical Centre, Utrecht, The Netherlands
e-mail: g.krings@umcutrecht.nl

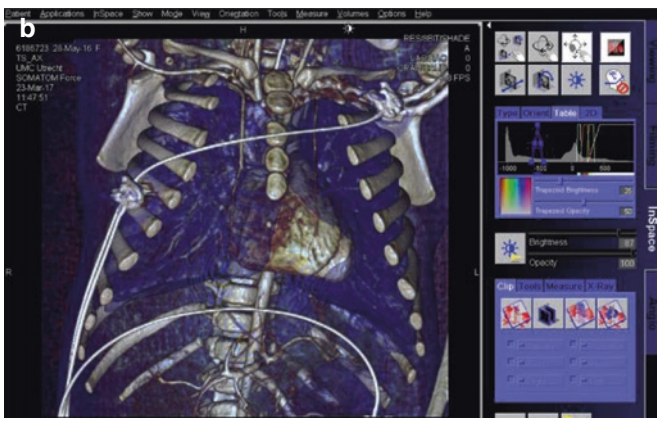
© Springer International Publishing AG, part of Springer Nature 2019
G. Butera et al. (eds.), *Atlas of Cardiac Catheterization for Congenital Heart Disease*,
https://doi.org/10.1007/978-3-319-72443-0_38

Fig. 38.2 3DRA acquisition

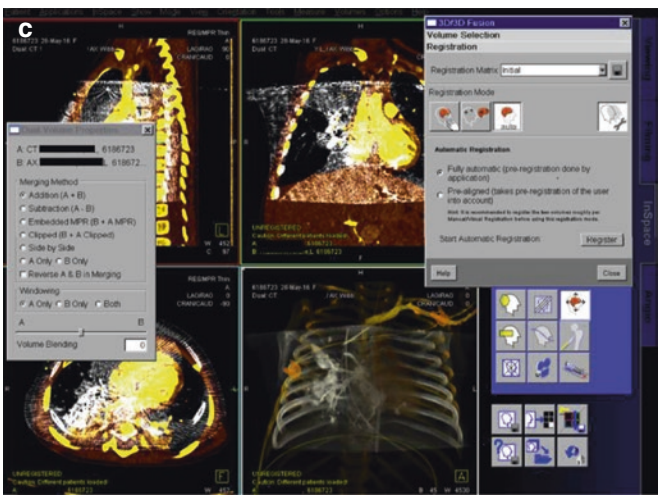




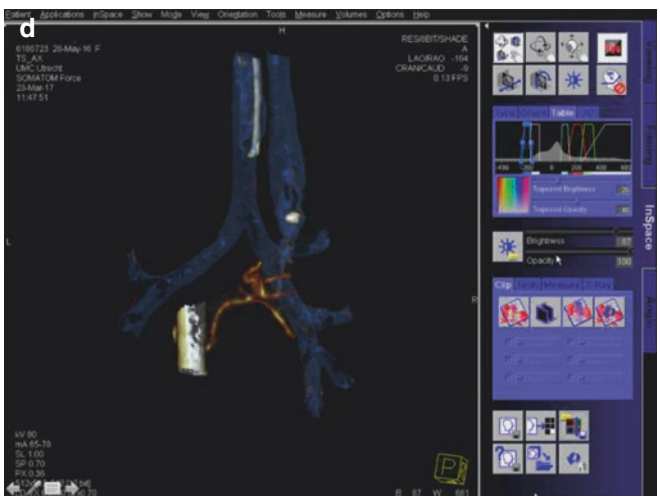
actual 3DRA
visualisation of right sided MAPCA's



import of previous CTA
on 3DRA workstation as second 3D dataset



registration of 3DRA and CTA
manual or automatic overlay



result after post processing:
3DRA and CTA information in one image

Fig. 38.3 3DRA: Fusion with previous CTA

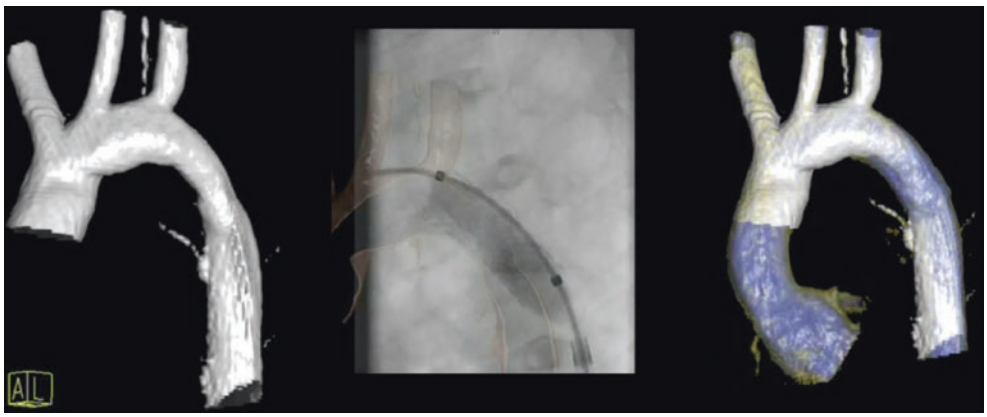


Fig. 38.4 Case 1: Coarctation stenting

3DRA in post surgical Re-CoA (8 kg weight)

1. contrast injection in LV guarantees homogeneous contrast in Aortic Arch
2. 3D roadmapping reduces contrast during stent placement
3. 3DRA pre and post intervention, optimal stent position and dimension

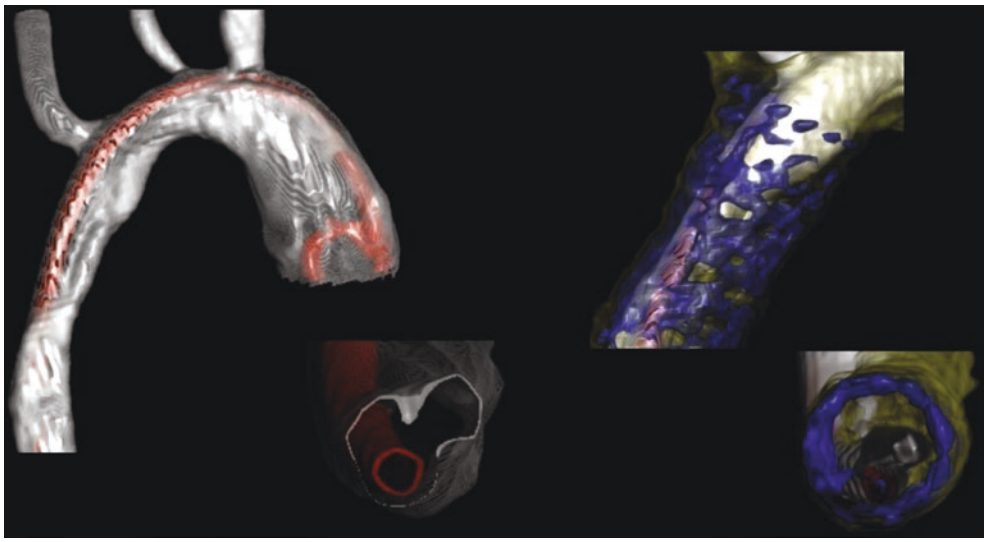


Fig. 38.5 Case 2: CoA dissection

3DRA post balloon dilatation in Re-CoA demonstrates dissection

1. dissection visualized in different cross sectional planes and hollowed aorta
2. stent indication based on dissection pattern and residual gradient
3. 3DRA post intervention demonstrates stent position (Cook Formula 10x20mm)

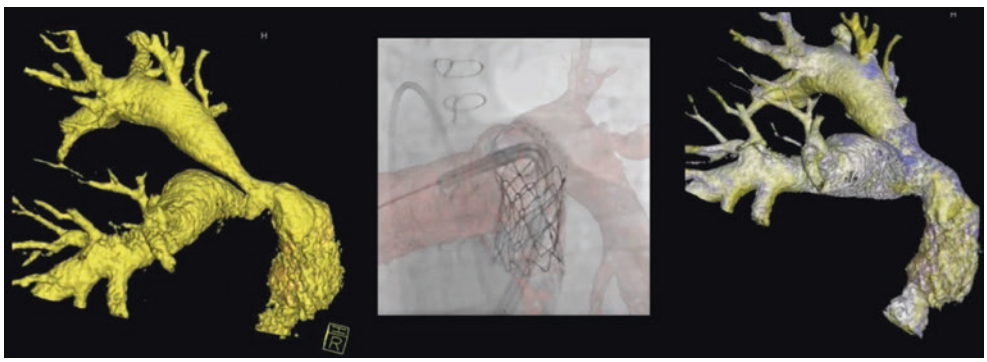
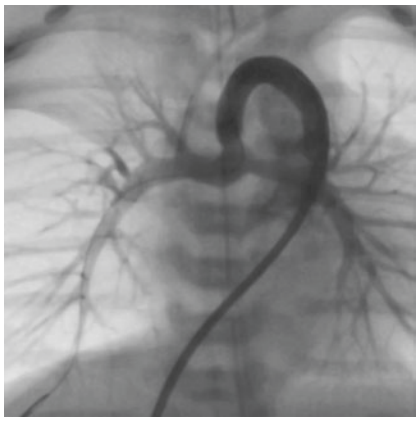


Fig. 38.6 Case 3: Bifurcation stenosis

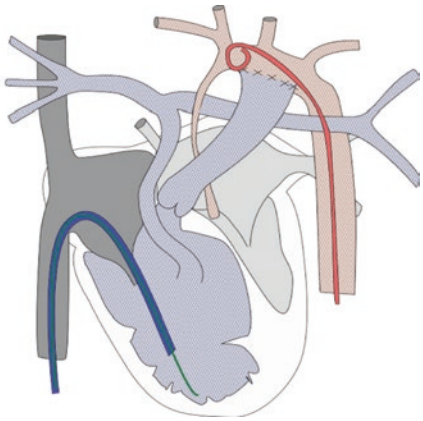
3DRA in complex pulmonary artery bifurcation stenosis and PPVI

1. visualisation of both PA branches and Melody valve in different cross sectional planes
2. Y stenting with telescope and anchor technique (ev3 Mega LD and ev3 Max LD)
3. 3DRA pre and post intervention demonstrate stent positions and dimensions



conventional angiography

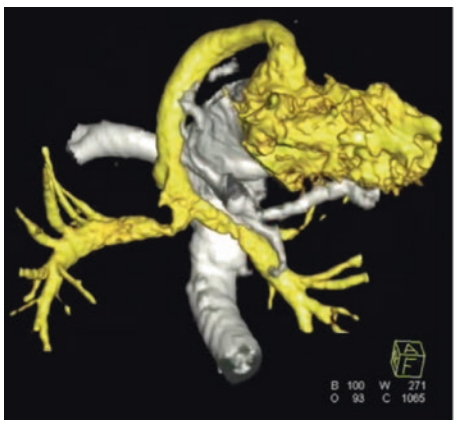
stenosis not visible



3DRA

injection protocol :
12 ml RV, 8 ml AoArch
pacing 220/min via long sheath

Fig. 38.7 Case 4: Sano shunt stenosis. HLHS, Norwood I, 5 mm Sano shunt. 3 days post-op: oxygen saturation 50–60%



3DRA with all-in-one visualization
severe RPA stenosis only visible in virtual caudal angulation neo aorta with coronaries in silver systemic RV, Sano shunt and pulmonary arteries in gold

3DRA and roadmap
3D image reduced to relevant structures and colour optimised, 3D projected on 2D frontal plane for intervention anatomic shift can occur and be adapted manually

Fig. 38.8 Case 4: Sano shunt stenosis. 3D visualizing of entire anatomy and guidance of stent implantation

38.3 Status Quo of 3DRA

The current systems use integrated workstations to automatically calculate and 3D reconstruct the scanned tissue within 10–20 s after rotation. The principle of contrast distribution in 3DRA is different from conventional angiography (CA) with a complex workflow including optional rapid pacing (Fig. 38.1), breath holding, and injection of diluted contrast simultaneously at multiple locations during 5–7 s. Post processing of the 3DRA dicom data is similar to CTA or MRA and allows for scissoring to hide irrelevant structures, threshold adaptation to visualize a specific range of Hounsfield units, use clipping planes and MIP views to measure, and virtually fly through anatomic structures. Projection of the post-processed 3D image to the CA screen enables for road mapping to guide complex procedures without the need for sequential localizing angiographies. Typical indications for 3DRA are aortic arch (AoS) stenosis, pulmonary artery or vein stenosis (PAS, PVS), interventions in pulmonary atresia (PA VSD), pulmonary valve implantation (PPVI), and interventions in single ventricle (SV) stages I–III.

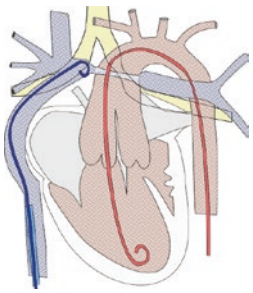
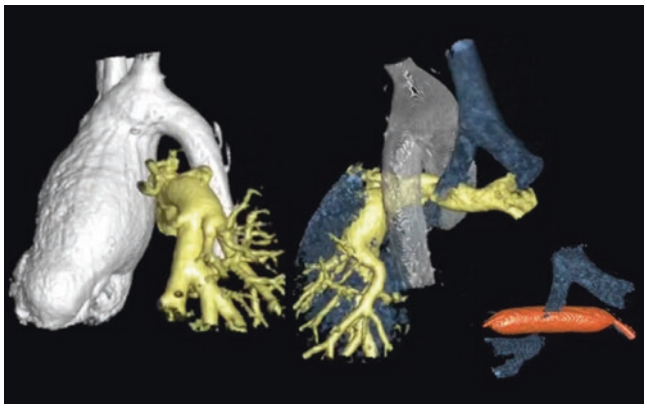


Fig. 38.9 Case 5: LPA stenosis in TCPC. 3D visualizing of entire anatomy and guidance of airway interrogation

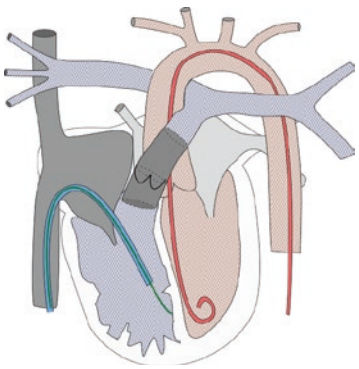
3DRA

injection protocol (50 kg):
25ml VCI and 25ml VCS,
50ml single Ventricle
internal pacemaker 180/min



two 3DRA's : diagnostic and interrogation

1. visualization of DKS, LPA and airway
2. LPA ballooning to check for bronchus compression



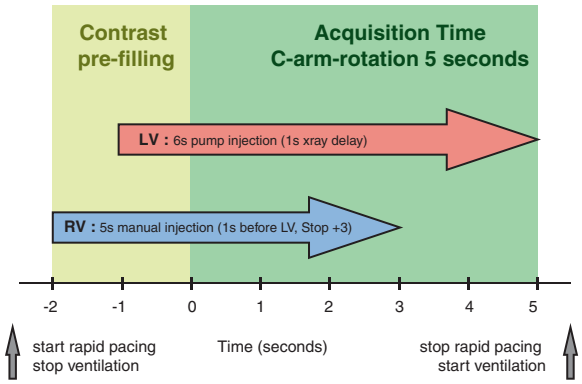
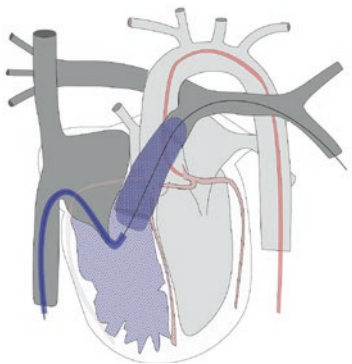


Fig. 38.10 Case 6: PPVI "entire heart protocol"

First 3DRA "Entire Heart Protocol" to visualize the entire anatomy in PPVI

1. RV contrast manually via long sheath, RV rapid pacing via same long sheath, LV contrast via injector
2. prefilling RV -2 s and stop at 3s, LV -1s with continuation until 5s
3. first 3DRA can be skipped when previous detailed CTA or MRA data are available



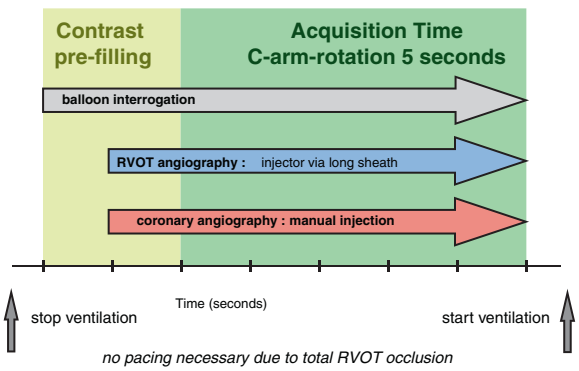


Fig. 38.11 Case 6: PPVI "interrogation protocol"

Second 3DRA "Interrogation Protocol" to visualize MPA and coronaries when ballooning

1. low amount RV contrast manually via long sheath during balloon interrogation MPA and simultaneous selective coronary angiogram
2. no rapid pacing necessary due to total MPA occlusion causing no-output
3. 3DRA visualizes precisely coronary artery and balloon – MPA topography

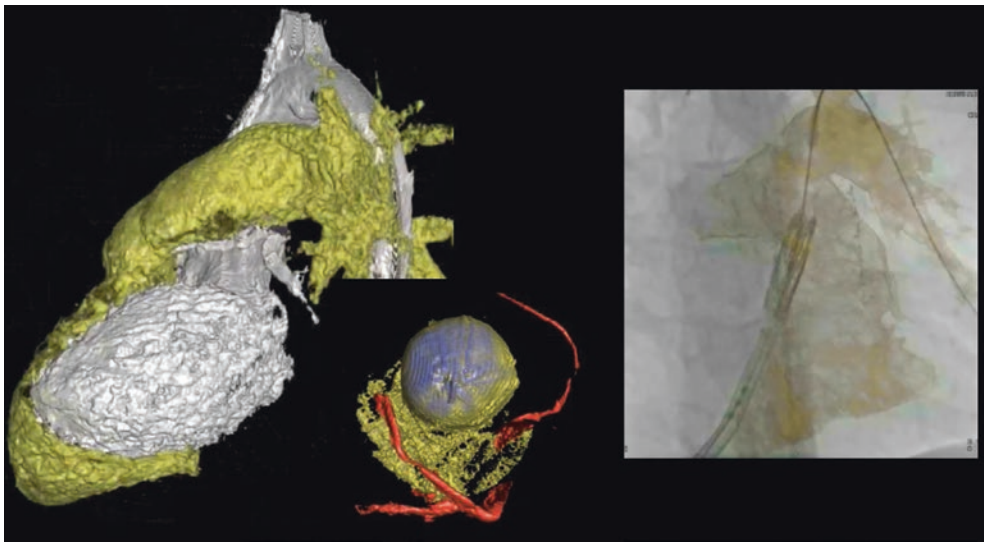


Fig. 38.12 Case 6: PPVI based on 3DRA

3DRA in standard PPVI :

1. Entire Heart and Interrogation 3DRA protocol in Fallot after transanulary patch
2. 3D based prestenting and implantation of Sapien 3 valve

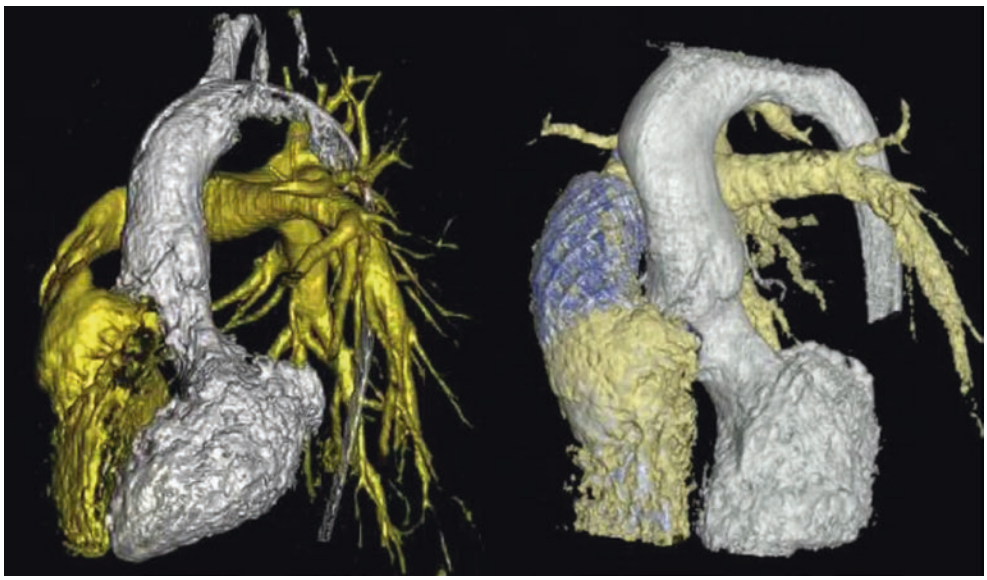


Fig. 38.13 Case 7: 3DRA in complex PPVI

3DRA pre and post PPVI in small child with severe retrosternal compression

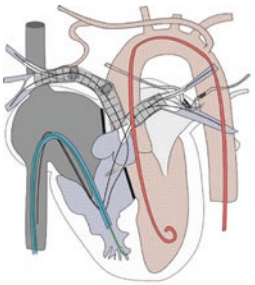
1. Fallot after transanulary patch, 22kg,
2. homograft failed twice due to retrosternal compression, sternum partly resected without improvement
3. 3DRA pre and post PPVI : prestenting with Andra XXL and 2 CP stents, implantation Melody 20mm

38.4 Multimodality

Previous CTA, MRA of 3DRA dicom data can be imported – the so-called merge or fusion – to generate overlay visualization and sometimes can substitute a 3DRA. Anatomical annotation of those data is based on bone structures.

38.5 Benefit of 3DRA

3DRA offers the ability to understand the entire anatomy in unrestricted angulations, thus delineating substrates not or hardly visible by CA. As with all kinds of new techniques, the benefit of 3DRA strongly depends on the user's confidence and trust in the resulting images. A validated algorithm



3DRA

36 ml RV (manual, long sheath)

36 ml LV (injector)

rapid pacing 220/min

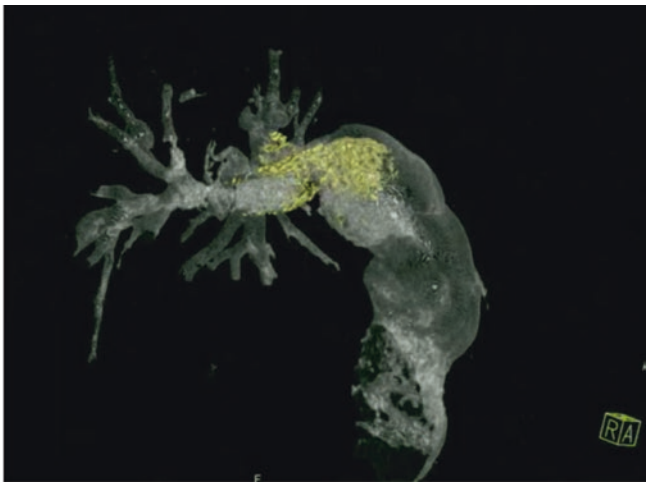


Fig. 38.14 Case 8: Complex PA VSD. A 3-year-old child with PA VSD after Melbourne shunt, unifocalization, multiple stent interventions, and implantation of Contegra valve during correction, severe distal MPA, and bifurcation stenosis post surgery

3DRA …

produces detailed 3D imaging

during interventions

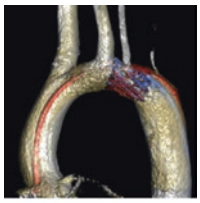
visualizes the entire anatomy

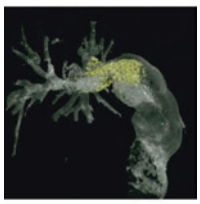
identifies critical interactions

enhances safety of interventions

offers guidance by 3D road mapping to

reduce contrast amount and radiation





3DRA still needs …

simplified workflow and workstations

biplane instead of monoplane 3D roadmapping

better correction of anatomical versus 3D shift

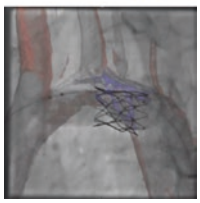


Fig. 38.15 3DRA conclusion

is essential covering contrast dilution and amount, injection locations, and timing as well as optimization of the systems radiation parameters. In an optimal setting, an "all in one run" scan can be performed with 0.5 mSv and a contrast amount equal to two CAs. In complex bi- and univentricular hearts, it will deliver information of the entire topography allowing for a safer procedure with less radiation and contrast compared to CA. Visualization of vessel-vessel as well as vessel-airway interaction will promote to defocus from the original target of the intervention and widen the horizon by identifying potential interactions to prevent complications. The following figures cover the workflow in general as well as its case-related adaptations in AoS, PAS, PVS, PA VSD, PPVI, and SV I–III.

The images demonstrated are derived from a Siemens' syngo DynaCT with a biplane Artis zee system. The results reflect a 6-year period of use in congenital heart disease with use of 3DRA in 70% of all interventions. Toshiba, Philips, and GE offer comparable equipment.

In conclusion 3DRA is a tool available during catheter interventions which enables to visualize all intrathoracic structures and their interactions. It helps to guide complex interventions, reduce radiation and enhance safety. Improvements of the available 3DRA systems are necessary in terms of post processing, 3D roadmapping with biplane projection and automized correction for anatomic shift (Fig. 38.15).

Video 1 Case 1. 3D rotational angiography in post-surgical re-coarctation (MOV 1544 kb)

Video 2 Case 2. 3D rotational angiography post-balloon dilatation in Re-CoA demonstrates dissection. A Cook Formula 10 × 20 has been implanted (MOV 4470 kb)

Video 3 Case 3. 3D rotational angiography in complex pulmonary artery bifurcation stenosis and PPVI. Both PA branches and Melody valve are visualized in different cross-sectional planes. Two stents across the bifurcation are implanted by using Y stenting with telescope and anchor techniques. Ev3 Mega LD and ev3 Max LD have been implanted. Finally, 3DRA shows pre- and post-intervention stent positions and dimensions (MOV 37640 kb)

Video 4 Case 4. Sano shunt anatomy and stenosis at the origin of the left pulmonary artery (MOV 3416 kb)

Video 5 Case 4. 3D rotational angiography road map for stent implantation in Sano shunt stenosis. Note the anatomic shift 2D versus 3D, correction of shift performed manually (MOV 10521 kb)

Video 6 Case 5. Left pulmonary artery stenosis in total cavopulmonary connection. It is possible to visualize DKS, left pulmonary artery (LPA), and airways. Furthermore, LPA ballooning is performed in order to check for bronchus compression (MOV 2600 kb)

Video 7 Case 6. Percutaneous pulmonary valve implantation (PPVI). Entire heart protocol and interrogation protocol (MOV 36490 kb)

Video 8 Case 7. Complex PPVI. Entire heart protocol and interrogation protocol (MOV 13243 kb)

Video 9 Case 8. A 3-year-old child with PA VSD after Melbourne shunt, unifocalization, multiple stent interventions, and implantation of Contegra valve during correction. Severe distal MPA and bifurcation stenosis post surgery are seen by using 3d rotational angiography (MOV 10623 kb)